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RESEARCH ARTICLE

# Relationship between bird-of-prey decals and bird-window collisions on a Brazilian university campus

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ABSTRACT. Bird-window collisions are a dramatic cause of bird mortality globally. In Latin America, statistics are generally very scarce and/or inaccessible so the frequency of such incidents is still poorly understood. Nevertheless, civilians have applied preventive methods (e.g. adhesive bird-of-prey decals) sparsely but, to our knowledge, no study has evaluated their effectiveness in Brazil. Here, we estimated the mortality rate of bird-window collisions and tested the effectiveness of bird-of-prey decals at preventing such accidents. We undertook daily searches for bird carcasses, presumably resulting from window collisions, near all buildings on a university campus over seven months. Adhesive bird-of-prey decals were then applied to the two buildings with the highest mortality rates and surveys continued for over 12 more months. The mortality rates before and after the application of decals and between seasons were then compared using Friedman test. We recorded 36 collisions, 29 around the two buildings with the highest collision rates 19 prior and 10 after our intervention with associated collision rates of 0.08 and 0.04 collisions/day. Although mortality was reduced by almost half, this difference was not statistically significant. The Blue-black grassquit, *Volatinia jacarina* (Linnaeus, 1766), and Ruddy ground dove, *Columbina talpacoti* (Temminck, 1810) suffered the highest number of collisions, followed by the Rufous-collared sparrow, *Zonotrichia capensis* (P. L. Statius Müller, 1776). Our bird-of-prey decals and efforts were insufficient to prevent or dramatically reduce the number of bird-window collisions. Therefore, we recommend that different interventions be used and additional long-term studies undertaken on their efficacy.

KEY WORDS. Environmental impact, fauna depreciation, human-made environment, Neotropical, preventive actions, urban birds.

## INTRODUCTION

Bird collisions with human structures (eg. vehicles, aircrafts, communication towers, wind turbines, power lines and buildings) are among the major anthropogenic causes of bird mortality in the world (Erickson et al. 2005, Jenkins et al. 2010, Rytwinski and Fahrig 2012, Calverti et al. 2013, Loss et al. 2014, DeVault 2015, Washburn et al. 2015, Santos et al. 2016). In North America alone, up to one billion birds are estimated to die due to collision with buildings (Loss et al. 2014, Klem 2015). However, what estimates exist are limited and they are largely extrapolations of data collected from a handful of locations in the Northern Hemisphere (Machtans et al. 2013), often without considering the spatial variation of the urban landscape (Hager et al. 2013). Furthermore, the frequency of collisions is typically underestimated as predators or scavengers often consume carcasses before they can be counted (Klem 2009a, Hager et al. 2012).

Human constructions with reflective glass are especially lethal, and have been considered one of the greatest causes of declines in global bird populations (but see Arnold and Zink 2011), second only to habitat loss (Klem 2006, 2009a). Several studies in North America reported bird collisions with tall window-covered buildings numbering in the thousands over both the short- and long-term, even in a single day (Erickson et al. 2005).

They occur because birds do not perceive windows as obstacles (Klem and Saenger 2013), especially when they can see the sky and surroundings reflected in the glass (Menacho-Odio 2015). It is estimated that about half of all collisions result in death (Klem 1990), but it may not be instantaneous, and many victims die as a result of subsequent shock, injury, or being more vulnerable to predation while recovering (Klem 1990, Parkins et al. 2015).

Virtually all flying birds are faced with the threat of window collision with occurrences having been reported for ~6% of all bird species (Klem 2006, 2009b). Vulnerability assessments to determine which species are at higher risk of collisions are important to understand the real impact of human infrastructure on birds and to inform practical management decision-making (Loss et al. 2014). In North America, upwards of one quarter of bird species have been listed as potential victims, regardless of sex, age or residency status (Klem 1989).

In Latin America, statistics about bird collisions with windows are generally very scarce and/or inaccessible, but a few publications are available. In Costa Rica, Menacho-Odio (2015) listed 131 species for which window collisions were reported based on museum specimens and published reports. In a local study in Mexico, Cupul-Magaña (2003) reported 15 fatal incidents (4.78 a month). In Colombia, Agudelo-Álvarez et al. (2010) detected 106 collisions over a 31-month period (3.41/month) on a university campus, and Ocampo-Peñuela et al. (2016a) recorded 90 bird collisions for 21 species in a rural residence from 2009 to 2012. Little is known about such incidents in Brazil, and there have been few studies published in the broader scientific literature (but see Barros 2010, Stolk et al. 2015). This underscores both the surprising lack of information about the impacts of bird-window collisions on bird populations and the absence of evaluations of the best management practices for preventing or reducing these accidents.

Several methods have been proposed in the Northern Hemisphere in an effort to reduce bird-window collisions, including both 2D adhesive decals and 3D mobiles simulating birds of prey, wind bells, flashing lights, UV markings and paintings, and stripes (Klem 1990, Klem and Saenger 2013, Oviedo and Menacho-Odio 2015, Rössler et al. 2015). In Brazil, adhesive bird-of-prey decals are sparsely applied to glass windows in cities and parks throughout the country but without standardization and unknown effectiveness. Indeed, to our knowledge, the effectiveness of these decals has never been properly tested in Latin America.

Given the widespread use of bird-of-prey decals as a preventative measure for bird-window collisions but the lack of empirical support, we aim to test their efficacy at reducing bird-window collisions at a local scale in Brazil. However, based on previous studies in the northern hemisphere (e.g. Klem 1990, Rössler et al. 2015) we predict that bird-of-prey shaped decals will be ineffective at reducing the number of bird-window collisions and that it is independent of season. We also estimate which species are prone to window collisions.

## MATERIAL AND METHODS

This study was conducted on the campus of the Federal University of São Carlos in Sorocaba, São Paulo, Brazil (47°31’28”W, 23°34’53”S) (Fig. 1). It is approximately 70 ha in extent and consists of patches of abandoned pastures, tropical savanna (‘cerrado’), secondary seasonal Atlantic forest, and small waterbodies (Fig. S1 – Suppl. material 1) (Viviani et al. 2010). Buildings cover 46,402 m$^2$ or nearly 6.5% of the total campus area (University City Hall, unpublished data). The dry season in the region is from April to September, and the rainy season from October to March (CEPAGRI 2016). Breeding in most tropical birds peeks during the rainy season (Wikelski et al. 2000).

We first estimated the mortality rate of bird-window collisions before any intervention was applied. We carried out daily surveys for bird carcasses, presumably resulting from fatal bird-window collisions, around eight buildings (Fig. S2 – Suppl. material 2), covering an area of approximately 18,000 m$^2$ and up to five meters away from each windowpane from 11 August 2014 to 8 March 2015 (262 days), usually between 1 and 3 pm. Our data was complemented by finds by reliable third parties, who were made aware of this study and assisted in collecting carcasses.

The two buildings with the highest collision rates were Aulas Teóricas e Laboratórios (hereafter ATLAB), and Gestão Administrativa (hereafter GAD). ATLAB covers 8,320.96 m$^2$ is 7 m high and has approximately 260 m$^2$ (3.1% of the total surface area) of translucent glass windows. It is mainly purple in color with several overhangs and awnings and is surrounded (to within 5 m) by lawns and scattered trees. GAD covers 1,067.53 m$^2$, 7 m high and has approximately 354 m$^2$ (33.2% of the total surface area) of reflective glass windows that received a dark film for filtering the incoming light. It is orange in color and surrounded by over a dozen trees and several shrubs, which provide shade at certain times of the day (see Fig. S2A, H – Suppl. material 2).

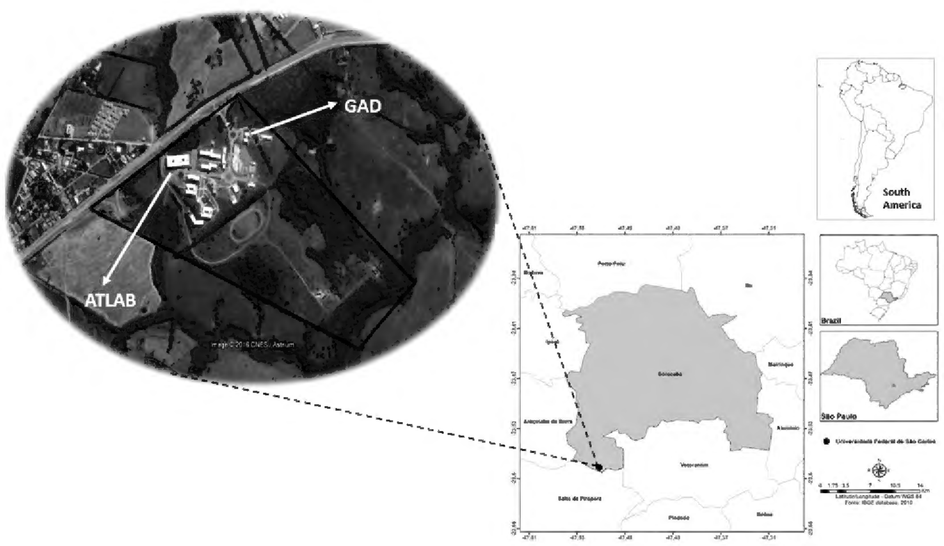


Figure 1. Location of the study area in Sorocaba, São Paulo, Brazil.

Figures 2–4. Windows of the ATLAB (2) and GAD (3) buildings following application of decals (4). See text for description.

We constructed 154 generalized bird-of-prey decals, 20 × 40 cm (0.08 s.m.), based on the photo (http://www.ideiasedicas.com/aulas-sobre-aves-falcao/falcao-voando). It was converted to silhouette-form using Gimp 2.8 to serve as a template that was traced onto adhesive white paper (Fig. S3 – Suppl. material 3). We chose white to be conspicuous against the dark windows. We attached 96 decals to ATLAB and 58 to GAD between March and May 2015 (while continuing to collect data), distributing them evenly by alternating between one or two windows (Figs 2–4). We distributed decals across as much of the exposed area of each building as possible but concentrated on places where the most carcasses were found, whilst access to other areas was restricted.

We continued surveys around GAD and ATLAB until 8 March 2016 (236 days). The total number of mortalities without and with decals and between the dry and wet seasons was then estimated and compared using the Friedman test and post hoc analysis using RStudio (R Development Core Team 2015).

## RESULTS

We recorded 36 fatalities resulting from collision with windows (0.07 fatalities/day) from twelve species (Fig. S4 – Suppl. material 4, Table S1 – Suppl. material 5). *Volatinia jacarina* (Linnaeus, 1766) and *Columbina talpacoti* (Temminck, 1810) were the most commonly recorded (n = 8 for both), followed by *Zonotrichia capensis* (P. L. Statius Müller, 1776) (n = 6). Four individuals could not be identified as a result of third-party information and/or carcasses that were in advanced states of decomposition. The buildings with the highest number of incidents were GAD (n = 21) and ATLAB (n = 8). Seven fatal collisions occurred at other buildings, but these were not included in our analyses. The total number of collisions in windows to which decals were applied (Fig. 5) was nearly half of that prior to intervention (n = 10; 0.04 collisions/day following intervention, compared to n = 19; 0.08 collisions/day prior to intervention). However, there was no statistically significant difference in the number of mortalities

Table 1. Bird-window collisions for two buildings (ATLAB and GAD) on the campus of the Federal University of São Carlos, Sorocaba, Brazil, during the wet (October to March) and dry (April to September) seasons, in windows without and with bird-of-prey decals. DS = dry season; WS = wet season. In parentheses, values expressed as (number of fatalities/day) x100*.

| Species | Without DS | Without WS | With DS | With WS |
|---|---|---|---|---|
| *Columbina talpacoti* (Temminck, 1810) | 0 | 2 (1.27) | 3 (1.96) | 1 (1.20) |
| *Pachyramphus validus* (Lichtenstein, 1823) | 0 | 1 (0.63) | 0 | 0 |
| *Sporophila caerulescens* (Vieillot, 1823) | 0 | 0 | 1 (0.65) | 0 |
| *Tachyphonus coronatus* (Vieillot, 1822) | 0 | 0 | 1 (0.65) | 0 |
| *Thraupis sayaca* (Linnaeus, 1766) | 1 (1.25) | 0 | 0 | 1 (1.20) |
| *Tangara cayana* (Linnaeus, 1766) | 0 | 1 (0.63) | 0 | 0 |
| *Turdus amaurochalinus* (Cabanis, 1850) | 1 (1.25) | 0 | 0 | 0 |
| *Volatinia jacarina* (Linnaeus, 1766) | 3 (3.75) | 2 (1.27) | 1 (0.65) | 1 (1.20) |
| *Zonotrichia capensis* (Statius Muller, 1776) | 0 | 5 (3.16) | 0 | 1 (1.20) |
| Unidentified | 0 | 3 (1.90) | 0 | 0 |
| *Athene cunicularia* (Molina 1782)** | | | | |
| *Zenaida auriculata* (Des Murs, 1847)** | | | | |
| *Geotrygon montana* (Linnaeus, 1758)** | | | | |

*Friedman Test – Asymptotic General Symmetry Test: maxT = 1.5309, p-value = 0.4189; Post hoc Test: WithoutDS – WithDS 0.9996196, WithoutWS – WithDS 0.7373508, WithWS – WithDS 0.9566645, WithoutWS – WithoutDS 0.6754943, WithWS – WithoutDS 0.9770326, WithWS – WithoutWS 0.4188987. **Sampled in other buildings (one accident each).

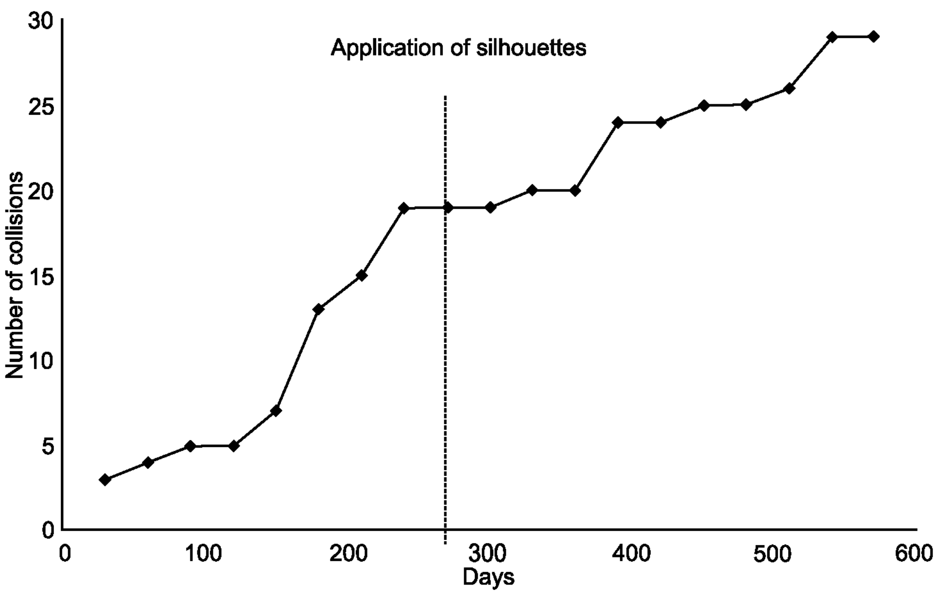


Figure 5. Total number of bird fatalities resulting from bird-window collisions in windows without and with bird-of-prey decals on the campus of the Federal University of São Carlos, in Sorocaba, Brazil.

between windows without and with decals or between season (MaxT = 1.53; p = 0.42); so collisions were neither influenced by decals or season (Table 1).

## DISCUSSION

Our data suggests that representatives of the Columbidae (e.g., *C. talpacoti*) and certain passerines (e.g., *V. jacarina* and *Z. capensis*) may be more prone to collision with windows. Birds having rapid flight and heavy bodies with small wings are less able to react swiftly to unexpected obstacles (Bevanger 1998). This is also in keeping with Rayner (1988) who determined that the relatively small thin wings of the Columbidae make them among the bird groups most susceptible to collisions. In North and Central America, nocturnal migrants, grouses, falcons, hummingbirds, and passerines such as warblers, manakins, sparrows and thrushes were the most likely victims (Gelb and Delacretaz 2009, Breithaupt et al. 2013, Klem 2014, Loss et al. 2014, Menacho-Odio 2015).

Overall, the collision rate is at least partially explained by the density of birds in the surrounding area (Sabo et al. 2016) as well as factors including age, sex, and behavior (Hager and Craig 2014, Kahle et al. 2016). Still, some species that occur at high densities in urban areas, such as the Rock Dove (*Columba livia*) and House sparrow, *Passer domesticus* (Linnaeus, 1758), may learn from experience to avoid windows (Klem 2014). In this study, the highest number of mortalities resulting from bird-window collisions was recorded for the building (GAD) with the greatest total and percentage area of windows and number of surrounding trees. This supports the findings of Gelb and Delacretaz (2009), Loss et al. (2014), Cusa et al. (2015), Ocampo-Peñuela et al. (2016a) and Bracey et al. (2016). They stressed that, apart from bird ecology and behavior, the number of windows and the percentage area of a built structure covered by windows influences the number of collisions. Collisions are also strongly dependent upon the surrounding landscape and its potential to attract birds (Hager et al. 2008, Hager and Craig 2014). In particular, Dunn (1993) related high collision rates in US winter homes to the fact that residents placed bird feeders next to their windows.

Although the daily collision rate decreased by half (0.08 to 0.04) following application of decals, this was not enough to generate a statistically significant difference. Given the lack of similar studies in Brazil, comparisons of the efficiency of our method are restricted to elsewhere in the world. Klem (1990) tested various methods in the USA, including similar bird-of-prey decals and 3D mobiles, wind chimes and flashing lights, but found no significant reduction in the number of collisions. He also found the largest reductions were associated with the application of horizontal or vertical stripes in a rectangular mesh. In Europe, Rössler et al. (2015) tested several methods using achromatic patterns and found that 2mm-wide stripes covering < 7% of a window were as effective as stripes of 13mm covering half of pane at reducing collisions. He also found that 10 cm long vertical stripes were more effective than horizontal stripes of the same size. In Costa Rica, people living in urban areas preferred mitigation structures that have a low cost, high aesthetic quality, and do not impair the passage of light or obscure views (Oviedo and Menacho-Odio 2015). Patterned glass, UV-reflective films and objects separated by 5-10cm have also proven effective (Klem 2009a). UV-reflecting adhesives (0.41 decals/m$^2$) applied to a residence in Colombia resulted in an

84% reduction in collisions (Ocampo-Peñuela et al. 2016b). However, UV reflection would only be efficient for birds with strong ultraviolet perception (including most passerines). For other groups, it would only be optimized under certain light conditions (Hastad and Ödeen 2014).

We also found no difference between seasons, but this requires verification by long-term studies. In the northern hemisphere, collisions tend to increase during the spring and autumn migrations (Gelb and Delacretaz 2009, Kahle et al. 2016). However, in Colombia, collisions occurred year-round but peaked in August and September (Ocampo-Peñuela et al. 2016b). In Bogota the number of accidents was higher in October, coinciding with the arrival of boreal migrants (Agudelo-Álvarez et al. 2010).

Unfortunately, the small scale and relatively low number of collisions recorded during our study limited the scope of analyses, even after 19 months of data collection across seasons. It is also possible that the stickered area was insufficient but this is a consequence of the method, which repeats the measures taken by the Brazil public. Thus, while we caution against making sweeping generalizations we conclude that our bird-of-prey decals and efforts were insufficient to reduce the number of bird-window collisions.

Houses, public buildings and facilities in protected areas commonly use similar birds-of-prey shaped decals in an effort to reduce bird collisions. However, our study suggests that their use is merely aesthetic and does not reduce the number of bird-window collisions, as desired. Therefore, we suggest that this tradition be abandoned and efforts should rather be encouraged to identify the factors most frequently associated with bird-window collisions (Gelb and Delacretaz 2009). Based on this, an effective protocol could be developed to incorporate the testing of a various interventions. This would include decals separated by up to 10cm (Klem 2009b, Ocampo-Peñuela et al. 2016b), 10 cm x 2 mm vertical stripes (Rössler et al. 2015) and avoiding "ecological traps", such as bird feeders near glass windows (Klem 1990, Klem et al. 2004, Krummer and Bayne 2015) in an effort to reduce collisions. The main goal would be to create a signal of any kind that allows birds to detect and avoid windows (US Fish and Wildlife Service 2016).

In North America, citizen scientists have proven to be strong allies in estimating the number of bird-window collisions (Machtans and Thogmartin 2014, Loss et al. 2015, Kummer et al. 2016a, b). We therefore recommend undertaking similar efforts in Latin America and that nationwide data on bird-window collisions be gathered in Brazil to develop effective public policies in urban management. Nevertheless, it is still necessary to produce robust local data on bird-window collisions and introduce preventive measures across Brazil.

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## Supplementary material 1

**Figure S1. Campus of the Federal University of São Carlos, Sorocaba, São Paulo, Brazil. A: administrative building (GAD); B: clinic; C: university restaurant; D: library; E: academic management; F: laboratories; G: lectures building; H: classroom and laboratories (ATLAB). Source: Google Earth.**

Authors: Thaís Brisque, Lucas Andrei Campos-Silva, Augusto João Piratelli

Data type: TIF file



## Supplementary material 2

**Figure S2. Views from the buildings on the campus of the Federal University of São Carlos, in Sorocaba, São Paulo, Brazil. A: administrative building (GAD); B: clinic; C: university restaurant (RU); D: library; E: academic management (G.A); F: laboratories; G: lectures building (AT); H: classroom and laboratories (ATLAB); I: departments building (CCTS).**

Authors: Thaís Brisque, Lucas Andrei Campos-Silva, Augusto João Piratelli

Data type: TIF file



## Supplementary material 3

**Figure S3. Bird-of-prey decals (20 cm × 40 cm) applied to buildings on the campus of the Federal University of São Carlos, Sorocaba, São Paulo, Brazil. See text for details.**

Authors: Thaís Brisque, Lucas Andrei Campos-Silva, Augusto João Piratelli

Data type: TIF file

### Supplementary material 4

**Figure S4. Birds fatalities after collision with windows in buildings on the campus of the Federal University of São Carlos, in Sorocaba, São Paulo, Brazil. A: Volatinia jacarina; B: Geotrygon montana; C: Pachyramphus validus; D: Zonotrichia capensis.**

Authors: Thaís Brisque, Lucas Andrei Campos-Silva, Augusto João Piratelli

Data type: TIF file



### Supplementary material 5

**Table S1: Total numbers of bird fatalities resulting from bird-window collisions on the campus of the Federal University of São Carlos, Sorocaba, Brazil, from August 2014 to March 2016. See Figures S1 and S2 for details.**

Authors: Thaís Brisque, Lucas Andrei Campos-Silva, Augusto João Piratelli

Data type: species data